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The Synergy between Meteorological Parameters and the Total Suspended Particles in the Atmosphere using Polynomial as Model

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ABSTRACT: Pollutants in the atmosphere are influenced by weather and chemistry thus making it difficult to know when they will concentrate and cause poor air quality. The only way to be sure of this is to monitor the air pollution at as many sites as possible and very often as well. In this study, particulate matter was captured at ten locations using SKC Air check XR5000 High volume Gravimetric sampler. The meteorological parameter was captured by LM-8000 Anemometer and with hydro thermograph -RS humidity /temperature meter .This study was conducted from May to October, 2010 in Sapele, Nigeria. The mean concentration range from156.25-850.70μg/m^3 while the correlation of suspended particulate matter with wind speed and temperature were both positive and the correlation of suspended particulate matter with relative humidity was negative. It was observed that the total suspended particulate matter correlated well with relative humidity and poorly with wind speed and temperature.
Keywords: *Spatial Variation; Meteorological; Urban area; Suspended Particulate matter, polynomial model.*

INTRODUCTION

The greatest air pollution in the Nigeria environment is re-suspended dust (Akeredolu, 1989; Ediagbonya *et al*., 2013). The term re-suspension is commonly used to include both suspension of newly generated particles and re-entrainment of previously deposited particles into the atmosphere (Nicholson, 1988) Re suspension, is a complex process that can be initiated by mechanical disturbances such as wind traffic-induced turbulence and type Stress, and construction activities. The windblown dust is often called natural dust because of its origin from mostly non-urban areas that are subject to suspension by wind (Chow *et al*., 1999).

In non-arid urban environments particulate matter can be made available from re-suspension in a variety of ways, including application of traction sands or de-icing salts, track-out from construction sites and other unpaved area .Air pollution does not always stay where it was made. In a stupefying short time, it can make its way around the globe. This process is called transport and dispersion and is very complex. There are many factors that influence the way pollution spread, including wind speed, relative humidity, atmospheric stability as well as the local terrain. Vehicle exhaust, tyre and brake tear, oil leaks and spills from vehicles wearing and maintenance of streets, and atmospheric deposition of anthropogenic particulate matter emissions (Claiborne *et al*., 1995).

Road dust is an agglomeration of contribution from several anthropogenic and biogenic sources of particulate matter (Rogge *et al*., 1993). In all road environments, the dust from various sources accumulates on road shoulders, near the curbs and along center dividers (Etyemezian *et al*., 2003). Re-suspension deposition, washout of materials on and off the road, and generation of new particles constitute a dynamic source and sink relationship in the traffic environment (Rogge *et al.,* 1993 Kuhn's *et al*., 2003). Paved and unpaved roads are among the largest emitters of particulate matter in many urban areas, and numerous studies have shown that traffics have influenced various sites (Stern Bick *et al*., 2002; Manoli *et al.,* 2002; Ruellan and Cachier, 2001; Pakkanen *et al*., 2001). (Kuplainen *et al*., 2003 and 2005) have studied the effects of road sanding on the composition and concentration of urban suspended road dust. The existing evidence suggests that certain sub-populations are particularly susceptible to acute Particulate matter (PM) exposure (Lipfer, 1978).

The most effective scavenger of the atmosphere is precipitation. Meteorological precipitation includes not only rain and drizzles but snow and other forms of water vapor in the solid phase. (Ediagbonya *et al*., 2013). The larger particles in the air are readily removed by falling rain drop (Wexler, 1961). The smaller particles may be accumulated in rain drops. This process is termed rain out rather washout. It has been reported that air pollutions may alter precipitation forming processes (Gun *et al.,* 1957).

While gravitational settling and impaction tap only the particles which are at the moment in the lowest air layers. The efficiency of rain scavenging by particle inertia and interception has been treated theoretically as a function of the size of the rain drop, size of the particle and their respective fail velocity and density (Greenfield, 1957; Chamberlain, 1953; Green *et al*., 1964; Jungo, 1963). Scavenging efficiency decreases with particle size and become negligible for particles 2μ and smaller. The small particles are removed by impaction with surface cover and aggregation to form larger particle which are removed by settling or washout. There have been few studies which have tried to model particulate matter using Non-Linear regression models (Lynch, 1970; Fletcher, 1984); which is one of the objectives of this study vis-à-vis perform a curve fitting that best fits our data. The objectives of this study are to establish a relationship between meteorological parameters and total suspended particulate matter, establishing a spatial distribution and toxic potential.

MATERIALS AND METHODS

Area of Study

The town Sapele is situated in the south-south geopolitical region of Nigeria with a population of about 135,800 (NPC 2005/2006). This study area is located on latitude N0050 50’ 0”-N005056` 0” and longitude E005037’0” – E005045’0``. The study area has a total area of 165.25 square kilometers. The map is shown in Figure 1.

Sapele is located near the junction of Jamieson and Ethiope rivers and about 80 mile (144 kilometers) from the sea, well closer into the timber yielding forest of the interior. Sapele is one of the first-rate wood industries in this region. It is also commercial city with four petroleum and allied industries. The climate is tropical with two distinct seasons, wet and dry. The major activities among the people of Sapele that generate particulate pollution are usually bush burning as a pre planting preparation, combustion of solid waste as a means of waste disposal, gas flaring, re-suspension of dust from unpaved road, and the production of charcoal which involves the burning of wood in an open space from dawn till dust in four different locations in the city. The charcoal is usually exported to other countries and sometime nearby cities.

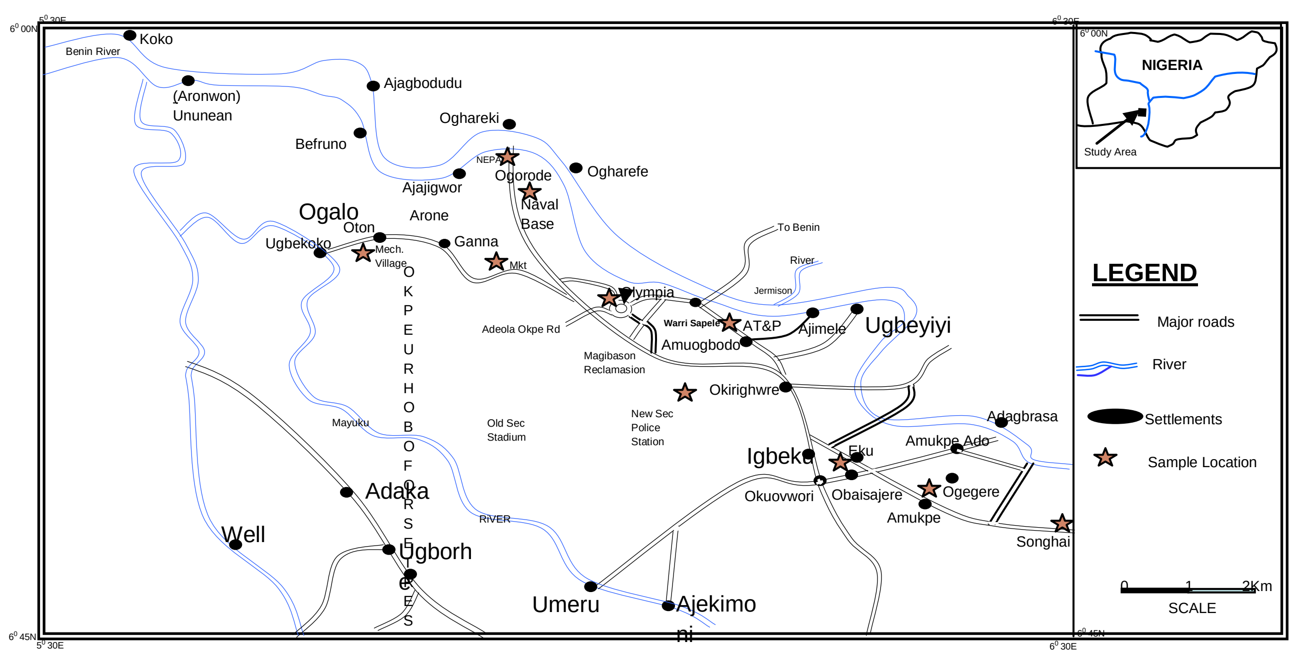

Figure 1: Map of Sapele Reflecting the Various Sampling Locations

Table 1: Site Code, Coordinates and Site Description in Sapele.

S/N	Site code	Co-ordinates	Site description
1	SP.MV	N05°51'53.5" E005°41'39.0"	The site was created at the mechanic village (shell Rd)
2	SP.SG	N05°51'025" E005°44'.37.4"	This was created at the Songhai
3	SP.NOR	N05°51'06.3" E005 44'45.4"	The site was created at new Ogorode Road.
4	SP.RH	N05°51'.33." E005°43'06.4"	The site was created at residential houses in Amoukpe area
5	SP.OJ	N05°53'24.8" E005°40'4.9"	The site was created at Olympia Junction
6	SP.SM	N05°54'05.9" E005°41'8.9"	The site was created at Sapele market
7	SP.IA	N05°55'16.8" E005°38'48.5"	The site was created at the industrial area
8	SP.NER	N05°52'28.6" E005°42'07.8"	This was created at New Eku Road
9	SP.SWR	N05°52'28.6" E005°42'07.8"	The site was created at Warri Sapele Road
10	SP.OK	N05°52'27.0" E005°43'40.7"	The site was created at Okirighwere

Ten monitoring sites were carefully selected to represent all the quarters of the city with high air pollution sources. These sites were created within the vicinities to reflect variation in traffic volume and human activities. Table 1 presents the monitoring sites and their co-ordinates. The monitoring sites were Geo-referenced by using Garmin GPS MAP 765 chart plotting receiver.

Sampler and Analytical Procedure

SKC Air check XR5000 High volume Gravimetric sampler Model 210-5000 serial No. 20537 and the I.O.M multi fraction dust sampler Institute of Occupational Medicine) – Edinburgh, United Kingdom.

A sampling device was used which includes sampling train with a air mover, a flow measuring device and a sample collection. A flow of air was created by the air mover which allowed the capture of contaminants in the air into the sample collection. The collection mechanism was made of cassette cover front plate, two-o-rings, cassette rear front and the sampler body which was connected to a vacuum pump with a Teflon tube. The inbuilt flow meter had a rating of 1000ml*/min* to 5000m1/min of air samples which was calibrated into 2000ml/min (2l/min). Before sampling, the unit was carefully calibrated against a standard meter to determine the quantity of air flows and all unloaded glass fiber filters were dried in the desiccators at room temperature. These particles were collected at a flow rate of 21/min for eight hours and the sampler was placed between heights of 1.5-2m to reflect the breathing zone of man.

The difference between the final weight and the initial weight was the amount of total suspended dust collected (Shaw, 1987; UNEP / WHO, 1994).

The Concentration in µg/m^3 was calculated by

$$\frac{\text{Final weight (mg) - initial weight (mg)}}{\text{Flow rate (m}^3\text{ min) x sampling period (min)}} \times 1000$$

For a quantitative estimate of the possible impact of the airborne particulate on the health of neighboring receptor, the toxicity potential (TP) of total suspended particulate matter (TSPM) were calculated by dividing its concentration for each sampling site with the daily average (250 µg/m^3) by FEPA, Nigeria Ambient Air Quality Standard.

Toxicity Potential (TP): Because of the exposure to particulate matter every day the tendency of human health effects exist. Thus toxicity potentials are calculated via:

$$TP = \frac{\text{Measured particulate matter concentration } (\mu g / m^3)}{\text{Regulatory limit for total suspended particulate matter } (250 \mu g / m^3)}$$

By definition, TP exceeding unity gives cause for concern.

Meteorological Parameters:

Air temperature and humidity were measured simultaneously four times a week during particulate sampling by using RS humidity/Temperature meter with resolution of 0.1%RH and 144^{O} C (Model RS 1364. RS Component Ltd. UK). Wind speeds were also measured using LM-8000 Anemometer (Heat miser UK) with resolution of 0.1 m/s. The particulate matter was captured four times a week fortnightly simultaneously with meteorological parameters for a period of Six months (May – October 2010).

Data Analysis:

Simple descriptive statistics were used in analyzing the data. Relationship analysis was done using correlation. Analysis of variance (ANOVA) was used to test for spatial variation and Nonlinear regression analysis was used to perform the curve fitting. The level of significance was set at 0.05. The analyses were done using the Statistical Package for Social Sciences (SPSS); while the curve fitting was done using MATLAB 7.5.

RESULTS AND DISCUSSION

The purpose of atmospheric sampling is to develop air quality criteria which are the basis for setting air quality standards. Data generated from this study was aimed at determining the spatial distribution of the total suspended particulate matter captured in this region. The regulatory limit for total suspended particulate matter is 150-230µg/m^3 for WHO and 250µg/m^3 for Nigeria's FMENV-. This body was hitherto called Federal Environmental Protection (FEPA). Presently, the body is now known as National Environmental Standards and Regulations Enforcement Agency (NESREA). At the ten monitoring sites the regulatory limits were clearly exceeded except in site 4, 6, 3, 8, 9 and site 7 which fell within the regulatory limit (Table 2)., The high particulate levels measured at all sites are caused by the combination of many high emitting vehicle, frequent traffic jam and combustion of solid waste. The reason for the regular traffic jams are high traffic density, unfavorable traffic handling and inadequate traffic discipline. From Table 2, the highest mean concentration recorded in site 8 (850.70µg/m^3) while the lowest mean concentration was recorded in site 4 (156.26µg/m^3).The spatial variations were remarkable and significant ($P<0.05$).

From Table 2, the range of toxicity potential is between 0.63-4. In sites SP.MV, SP.SG, SP.RH, SP.SM, and SP.NOR, the toxicity potentials were less than unity. While in sites SP.OK. , SP. SWR, SP.NER, SP.OJ, and SP.IA. The toxicity potentials were more than unity. Table 3 shows the range and the mean ambient temperature, relative humidity and wind speed during wet season in Sapele. From Table 4 below, there was no significant linear relationship ($P < 0.05$) between the meteorological parameters except for TSP against Relative humidity which gave a strong negative correlation ($r = - 0.66$) .The correlation of particulate matter with meteorological parameter had been studied elsewhere. (Gupta *et al*., 2004, Wojas, and Almguist,, 2007; Hamdy, 2005).

The correlation between Total suspended particulate matter and wind speed.

From Figure 1, the correlation is positive between total suspended Particulate matter and wind speed ($r = 0.24$), but this relationship was not significant ($P<0.05$), that is, there was no significant linear fit between TSP and wind speed. This gave rise to trying a non-linear fit using MATLAB 7.5, which gave a cubic relationship explaining 73.5% of the relationship. The effect of wind speed on pollutants is twofold: one effect is that wind speed will determine the travel time of a pollutants from sources to receptor. The other effect is the amount of pollutant dilute in the wind ward direction. According to Hosler, (1961) the persistence of surface wind speeds less than 3.1m/s is usually conducive to the accumulation of air pollutant. The polynomial helps to compensate for the failure in the linear trend line fit between TSP and meteorological parameter.

The Correlation between Total suspended particulate matter and relative humidity.

From Figure 2, the relative humidity correlates negatively($r = -0.66$) with suspended particulate matter. But this relationship was not significant ($P<0.05$), that is, there was no significant linear fit between TSP and Relative humidity. This gave rise to trying a non linear fit using MATLAB 7.5, which gave a polynomial of degree four (4) relationship explaining 70% of the relationship. Humidity is the amount of water vapor in the atmosphere. Particulate matter is hygroscopic in nature. As the relative humidity increases PM decrease. Therefore, the higher the relative humidity, the smaller the particulate in the atmosphere, the adsorption of water vapour onto the particulate matter may increase their settling rates and deposition.- link this to past reports

The correlation of Total suspended particulate matter with Temperature.

From Figure 3, the Wind speed and relative humidity are not sufficient enough to expound lucidly the variability in the concentration of total suspended particulate matter in the atmosphere hence the analysis of the atmosphere temperature with tota suspended particulate matter. However, the correlation between total suspended particulate matter and temperature showed positive relationship (r = 0.47). Higher temperature increases the reactivity of gaseous constitutes in the atmospheric air resulting in greater particulate production. But this relationship was not significant ($P<0.05$), that is there was no significant linear fit between TSP and Temperature. This gave rise to trying a non-linear fit using MATLAB 7.5, which gave a cubic relationship explaining 87% of the relationship.

Table 2: The Suspended Particulate Matter and the Toxicity Potentials of the Various Locations in Sapele.

S/N	Site code	Range µg/m^3	Mean (µ g/m^3)	Regulatory Limits	Toxicity Potential
1.	SP. MV	104.17-312.50	190.98± 102.41	WHO 150-230 FMEN&HD 250	0.76
2.	SP. SG	104.17-312.50	173.00± 85.05	"	0.69
3.	SP. NOR	104.17-312.50	208.33± 65.87	"	0.83
4.	SP. RH	104.17-208.33	156.25± 57.05	"	0.63
5.	SP.OJ	104.17-416.67	260.00±109.25	"	1.04
6.	SP.SM	104.17-312.50	190.98± 78.39	"	0.76
7.	SP. IA	312.50-625.00	312.50± 625.00	"	2.01
8.	SP. NER	625.00-1145.83	850.70± 202.16	"	3.40
9.	SP .SWR	208.33-312.50	295.14± 42.52	"	1.18
10.	SP.OK	208.33-416.67	329.86 ± 78.42	"	1.32

Table 3: The Ambient Temperature, Relative Humidity and Wind Speed During Wet Season in Sapele

S/N	Site code	Ambient temperature (^oC)		Relative humidity (%)		Wind Speed(m/s)	
		Range	Mean	Range	Mean	Range	Mean
1.	SP.MV	25.80-33.20	29.20	70.00-82.00	75.00	0.0-1.7	0.85
2	SP.SG	26.70-30.90	28.00	76.20-96.40	84.40	0.0-1.7	0.90
3	SP.NOR	27.40-32.00	29.00	75.70-93.80	83.76	0.0-1-5	0.75
4	SP.RH	27.00-29.00	27.90	78.60-93.40	85.00	0.0-0.5	0.25
5	SP.OJ	28.60-30.20	29.30	70.60-90.60	79.60	0.0-1.4	0.65
6	SP.SM	28.90-30.20	29.20	70.70-90.50	81.20	0.0-1.9	0.80
7	SP.IA	27.90-34.00	29.60	65.90-85.10	74.20	0.0-0.9	0.45
8	SP.NER	28.10-31.20	29.60	69.00-79.00	73.00	0.0-1.8	0.95
9	SP.SWR	27.40-3100	29.70	70.00-84.00	76.80	0.0-1.4	0.60
10	SP.OK	28.00-31.00	29.90	76.00-94.00	84.10	0.0-1.0	0.50

Table 4: Inter-Meteorological Parameters Correlation

	Relative Humidity	Temp	TSP	Wind Speed
Relative Humidity	1.00	-0.56	-0.66 *	-0.31
Temp	-0.56	1.00	.466	0.08
TSP	-0.66 *	0.47	1.00	0.24
Wind Speed	-0.31	0.08	0.24	1.00

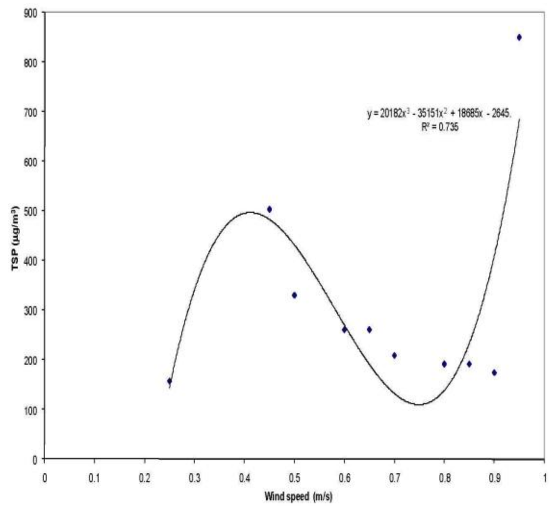

Figure 2: Correlation of Mean TSP with Mean Wind speed in Sapele, Nigeria.

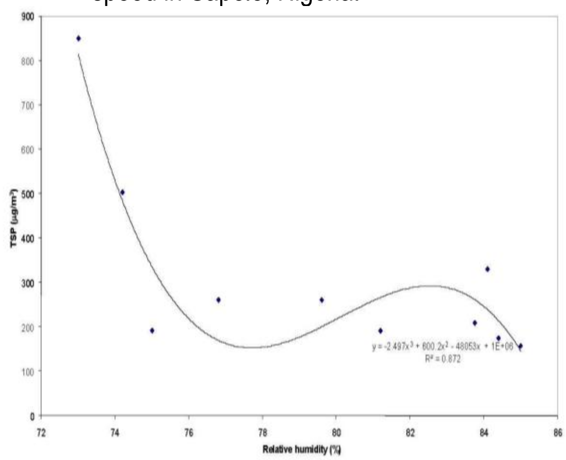

Figure 3: Correlation of Mean TSP and Mean Relative Humility in Sapele, Nigeria.

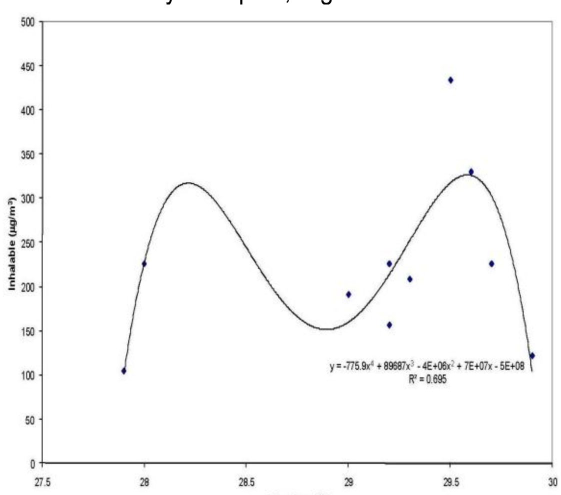

Figure 4: Correlation of mean TSP with mean ambient temperature in Sapele, Nigeria.

CONCLUSION

The total suspended particulate matter was captured in ten different locations in Sapele using SKC High Volume Gravimetric Sampler, glass fiber. The meteorological parameters for locations were also captured using Anemometer and hydro-thermograph.

The data obtained in this work showed that there where spatial distribution of the total suspended particulate matter. The correlation of wind speed and temperature was positive while the correlation of total suspended particulate matter with humidity was negative. The smaller the wind speed and the relative humidity lead to higher accumulation of particulate matter (PM) in the atmosphere while the higher the ambient temperature leads to increase in particulate matter (PM) in the atmosphere. The implication on environment and health not explained

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REFERENCES

Akeredolu, F.A. (1989). seasonal venation in deposition Rates. Concentrations and chemical composition of particulate matter in Ile-ife, Nigeria. *Atmospheric Environment*, **23:**783.

Chamberlain, A.C. (1963). Aspects of travel and deposition of Aerosol and vapor divides A.E. R.E Rapt Hp I R 1261. *At Energy Ret Estab, Harwell, Great Britain* 1953

Chow, J.C., Watson, J.G., Green, M.C., Lowenthal Dlt, Dubios D.W., kow Gillips J., Rogers C.F., Frazier C.A. and Cates W. (1999). Middle and neighborhood – scale variations of PM10 source contributions in Las Vegas, Nevada *Journal of Air Waste Manage Association,* **49:** 641-654.

Claiborne, C, Mitra, A., Adams, G., Bamesberger, L., Allwine, G., Kantamaneni, R., Lamb, B. and Westberg, H. (1995). Evaluation of PM10 Emission rates from paved and unpaved roads using tract techniques. *Atmospheric Environment,* **29:** 1075-1089

Ediagbonya, T.F, Ukpebor, E.E., Okieimen, F.E, Okungbowa, G.E. (2013).Spatio Temporal Distribution of Inhalable and Respirable Particulate Matter in Rural Atmosphere of Nigeria. *Environmental Skeptics and Critics*, **2(1):** 20-29.

Fletcher, R.A. (1984). A Review of Personal/Portable Monitors and Samplers for Airborne Particles, *Journal of the Air Pollution Control Association*, **34(10):** 1014-1016.

Greenfield, S.M. (1957). Rain scavenging of radioactive particulate matter from the atmosphere. *Journal of Meteorology,* **14:** 115-125.

Gunn, R. and Philips, B.B. (1957). An experimental investigation of the effect of air pollution on the initial of rain. *Journal of Meteorology*.**14:** 272-280

Gupta, A.K. Pattl, R.S. and Gupta S.K. (2004). A Statistical Analysis of Particulate data sets for Jawa Harlal HeHru-port and Surrounding Harbour Region in India. *Environmental Monitoring and Assessment,* **95:** 295-309.

Haagen-smit, A.J. (1965). Particulate clouds: Dusts smoke and mists. Their physics and Physical Chemistry and Industrial and Environmental aspects. *Science*, **147(3660):** 855-856

Hamdy, K.E. (2005). Dependence of urban air pollutants on meteorology science. *Total Environment,* **350:** 225-237.

Hosler. A.C. (1964). Air pollution and meteorology. *Metrology,* **14:**117

Junge, C.E. (1963). *Air chemistry and Radioactively*, Academic press New York.

Kuhns, H., Etyemezian, V., Green, M., Hendrickson, K., McGown, M., Barton, K. and Pitchford M. (2003). Vehicle based road dust emission measurement part III: Effect of precipitation, wintertime road sanding and street sweepers on inferred PM10 emission potentials from paved and unpaved roads. *Atmospheric Environment* **37:** 4573-4582.

Kupiainen, K.,Tervah, A.H. and Raisanen, M. (2003). Experimental Studies about the impactof traction sand on urban road dust composition. *Science of Total Environment,* **308:**175-184

Kupiainen, K.J., Tervahattu, H., Raqisanen, M., Makela, T., Aurela, M. and Hillamo, R. (2005). Size and composition of airborne particle from wear, tires and traction sanding. *Environmental Science Technology*, **39:** 699-706

Lipsett, M., Hurley, S and Ostroi, B. (1997). Air Pollution and Emergency Room Visits for Asthma in Santa Clara country California. *Environment Health Perspectives,* **105:** 216-222

Lynch, J.R. (1970). Evaluation of size-selective presamplers: I. Theoretical cyclone and elutriator relationship. *American Industrial Hygiene Association. Journal*, **31:** 548

Manoli, E., Voulsa, D. and Samara, C. (2002). Chemical characterization and source identification/ apportionmt of fine and coarse air particles in Thessalonk. *Journal Greece Atmospheric Environ*ment, **36:** 949-961.

National Environmental Standards and Regulations Enforcement Agency (NESREA) (2007). *Federal Republic of Nigeria Official Gazette* No.92 Vol.94

National Population Census Nigeria, (2005/2006).

Nicholson, K.W. and Branson, J.R. (1990) Factors affecting re-suspension by road traffic. *Science of Total Environment,* **93:** 349-358

Pakkanen, T.A., Loukk, O.K., Korhonen, C.H., Aurela, M., Makela, T., Hillamo, R.E., Aarnio, P., Koskentaio, T., Jousaq, A. and Maenhaut, W. (2001). Sources and chemical composition of atmospheric fine and copurse particle in the Helsinki area. *Atmospheric Environment,* **35:** 5381-5391.

Rogge, W.F., Hildemann, L.M, Mazurek, M.A., Cass, G.R. and Simonelt, B.R.T. (1993). Sources of fine organic Aerosol 3. Road Dust Tire Debris, and organometallic Brake Lining Dust-Roads as sources and sinks. *Environmental Science Technology,* **27:** 1892-1904.

Ruellan, S. and Cachier, H. (2001). Characterizations of fresh particulate vehicular exhaust near a Paris high flow road. *Atmospheric Environment,* **35:** 453-468

Shaw, R.W. (1987). Air Pollution by particles. *Scientific American*, **257:** 96-103

Sternbeok, J., Sjodin, A. and Andreasson, K. (2002). Metal emissions from road traffic and the influence of resuspension-results from two tunnel studies. *Atmospheric Environment,* **36:** 4735-4744.

UNEP/WHO. (1994). GEMS 310 / *Air Methodology Reviews. Measurement of suspended particulate matter in ambient air*. WHO/EOS/94.3/UNEP/ GEMS/94.UNEP Nairobi.

Wexler, H. (1961). Word Health organ, *monograph* S.F 46.

Wojas, B. and Almguist, C. (2007). Mass Concentrations and Metals Speciation of PM2.5 PM10 and total suspended solids in Oxford, Ohio and Comparison with those from metropolitan sites in the Greater Cincinnati region. *Atmospheric Environment,* **41:** 9064-9078.